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THE LONG-TERM EFFECT OF HIGH- AND LOW-RATE RESPONDING HISTORIES ON FIXED-INTERVAL RESPONDING IN RATS

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Ten rats were given extended lever-press training on a fixed-interval (FI) 30-s food reinforcement schedule from the outset or following exposure to one or two previous reinforcement schedules. For 4 rats the previous schedule was either fixed-ratio 20, which generated high response rates, or differential-reinforcement-of-low-rate 20 s, which produced low response rates. For 4 additional rats the extended training on FI 30 s was preceded by experience with two schedules: fixed-ratio 20 followed by differential-reinforcement-of-low-rate 20 s; or the same two schedules in the reverse order. Fixed-interval response rates were initially affected by the immediately preceding schedule, but after 80 to 100 sessions, all traces of prior schedule history had disappeared. The results also showed no long-term effect of schedule history on the interfood-interval patterns of responding on the FI 30-s schedule. These results support one of the most central tenets of the experimental analysis of behavior: control by the immediate consequences of behavior.

Key words: fixed interval, fixed ratio, differential reinforcement of low rates, schedule history, lever press, rats

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It is surprising that there has not been more research on the question of whether or not a history of responding on one schedule of reinforcement has a lasting effect on responding on another schedule of reinforcement. Ferster and Skinner (1957) argued that there was little evidence of such lasting effects but provided no specific empirical support for this claim. Since then, additional research dealing with this issue has appeared, but the results have been equivocal. The general approach has been to train subjects on a reinforcement schedule (the *history* schedule) that generates either high or low response rates before switching the subjects to a new reinforcement schedule (the *target* schedule) that provides an opportunity to assess the behavioral effects of the prior schedule history.

Some authors (Johnson, Bickel, Higgins, & Morris, 1991; LeFrancois & Metzger, 1993; Urbain, Poling, Millam, & Thompson, 1978; Wanchisen, Tatham, & Mooney, 1989; Weiner, 1969) have reported data implying that response rates on fixed-interval (FI) schedules are irretrievably affected by prior exposure to schedules that generate high or low response rates. All of these researchers, with the exception of Weiner who used humans, employed rats as subjects. All used differential-reinforcement-of-low-rate (DRL) schedules to generate low response rates before exposing the subjects to an FI schedule. Most used fixed-ratio (FR) schedules to produce high response rates prior to FI training, although Wanchisen et al. used a variable-ratio (VR) schedule for that purpose. Two of these researchers introduced additional experimental manipulations during exposure to the target FI schedules.

Other researchers have reported only transitory effects of schedule history on FI responding (Baron & Leinenweber, 1995; Cohen, Pedersen, Kinney, & Myers, 1994; Freeman & Lattal, 1992). Cohen et al. and Freeman and Lattal employed pigeons in their research, whereas Baron and Leinenweber used rats. Baron and Leinenweber used a multiple VR 20 extinction schedule, a mixed VR 20 extinction schedule, or a simple VR 20 schedule as the history schedule and FI as the target schedule. Freeman and Lattal employed a multiple FR DRL schedule as the history schedule and a multiple FI FI schedule as the target schedule, the FI components in the latter being identified by the same discriminative stimuli that had been associated with the FR and DRL components earlier. Cohen et al. used a progressive-ratio (PR) sched-

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ule instead of FI as the target schedule. In their PR schedule, the initial response requirement was FR 8, but after each food delivery the ratio was increased by eight. Training was continued until the rats stopped responding.

Although such variables as species, type of target schedule, or type of history schedule may be partly responsible for the discrepant results in the research to date, lack of sufficient training on the target schedule is likely the chief reason that some researchers have found history effects to persist. Two of the three studies that found that history effects disappeared provided extended training on the target schedule. Baron and Leinenweber (1995) assessed behavior on the target schedule for 90 sessions for all but 1 rat, and Freeman and Lattal (1992) exposed their pigeons to 60 sessions on the target schedule. Cohen et al. (1994) conducted the target schedule for only 30 sessions, but their study was unique in using a PR schedule as the target schedule. By contrast, the studies that found history effects to persist typically provided less training on the target schedules. Weiner (1969) collected data for only 10 sessions on each of four different FI schedules following exposure to FR and DRL. LeFrancois and Metzger (1993) examined FI target behavior after exposure to DRL, or to DRL followed by FR, for only 18.5 sessions on average, with 27 sessions being the largest number of sessions examined. Wanchisen et al. (1989) studied their rats for only 30 (in one case 40) sessions in each of two FI target conditions, each one following exposure to VR 20. Johnson et al. (1991) collected target FI data for an average of only 19.5 sessions following exposure to DRL or FR, before changing the conditions under which the FI data were obtained by withdrawing the water bottle that had been present in the chamber until then. Urbain et al. (1978) tested their rats on FI following FR or DRL histories for only 15 sessions before changing the conditions by administering *d*-amphetamine. In all these studies, history effects were still evident when testing of the target schedule was terminated or was interrupted by a change in conditions.

Weiner (1969) showed that response distribution during the interreinforcement interval on an FI schedule in humans differed from that often reported for nonhumans. Instead of either the smooth scalloping (e.g., Ferster & Skinner, 1957) or the break-and-run pattern (e.g., Cumming & Schoenfeld, 1958) typically reported in nonhumans, Weiner found a mixture of high and low but steady response rates throughout the interreinforcement intervals in humans on FI. This effect was found regardless of whether or not there had been prior exposure to DRL or FR schedules. Weiner hypothesized that the differences in the patterns of interreinforcement-interval responding in nonhumans and humans were due to schedule history. He argued that human subjects have likely had much more exposure to a variety of reinforcement schedules prior to any experimental intervention than their relatively naive nonhuman counterparts.

Wanchisen et al. (1989) tested this hypothesis by comparing interfood-interval patterns of response in rats exposed to FI 30 s alone, or following training on VR 20. Their results supported Weiner's (1969) hypothesis in that FI responding between reinforcers was at a high and steady rate when FI followed VR but consisted of a mixture of scallops and break-and-run patterns when FI was not preceded by VR. It must be noted, however, that the response-rate data from this study revealed that responding had not yet recovered from the VR history when the patterning data were examined.

Baron and Leinenweber (1995) also tested Weiner's (1969) hypothesis by training rats on an FI 30-s schedule from the outset, or following exposure to a simple VR 20, to a multiple VR extinction, or to a mixed VR extinction schedule. They found that after 90 sessions on FI, all rats developed an interfood responding pattern consisting mainly of breaks and runs with occasional episodes of a single response, regardless of schedule history. Contrary to Weiner's hypothesis, variability in type of schedule history had no long-term effect on patterning.

Freeman and Lattal (1992) also found no differences in response patterning during interfood intervals in either component of a multiple FI FI schedule in which the discriminative stimuli had previously been associated with the separate components in a multiple FR DRL schedule. They also reported that an inspection of cumulative records suggested that the FI performance consisted of a mixture of breaks and runs and scallops.

As was the case for response rate, the research to date on response patterning within the interfood intervals in FI as a function of schedule history has been equivocal. But also, as was the case for the response-rate data, the confusion may be related to amount of training on the target schedule. Wanchisen et al. (1989) found steady high response rates between FI food presentations following exposure to VR and scalloping and break-and-run patterns when FI training occurred from the outset, but the rats were tested for only 30 (in one case 40) sessions. Baron and Leinenweber (1995) and Freeman and Lattal (1992) both found break-and-run patterns regardless of schedule history after testing their animals for 90 and 60 sessions, respectively.

The present research was designed to expose rats to one or two history schedules before they were switched to FI and then to continue FI exposure until response rates appeared to be asymptotic. Moreover, the design allowed an examination of the effects on FI performance of exposure to FR alone, DRL alone, or to both schedules in succession. In addition, data were collected from 2 rats exposed to FI 30 s without any specific prior history to provide a reference baseline against which to compare FI behavior after the various schedule histories. Finally, in addition to examining response rates on FI, the present research provided an opportunity for further assessment of the effect of schedule on response patterning within the interfood intervals on the FI target schedule.

METHOD

Subjects

Ten experimentally naive male hooded rats (*Rattus norvegicus*) of the Long-Evans strain obtained from the Charles River Company were maintained at 80% of their ad lib weights by means of a food-restricted diet. Access to water in the home cage was unlimited. The rats were approximately 120 days old at the start of the experiment. They were housed individually in clear plastic 2-rat shoebox-style cages in a room reserved for the housing of rats. The temperature was maintained at 23 °C and the light cycle was 12 hr of fluorescent light and 12 hr of darkness. The light was white except during the first and last hours of the lighted period, when it was red. The rats were treated in accordance with the Ethical Guidelines of the Canadian Council on Animal Care.

Apparatus

A standard Gerbrands operant conditioning chamber with interior dimensions of 29 cm by 23 cm by 19 cm high was used. The chamber had two levers, each 6.0 cm wide, 1.5 cm thick, and protruding 1.5 cm into the chamber through a slot in the wall. The levers were mounted side by side, their centers 8.5 cm above the floor and 11.5 cm from the left and right side walls. Only the left lever, which required a force of about 0.44 N to depress completely, was operable, the right lever having been immobilized by means of a clamp attached to the portion of the lever that extended beyond the feeder wall. The feeder tray was centered on the same wall just above the floor and could be reached through an opening (2.5 cm wide by 3.0 cm high). A Gerbrands feeder dispensed 45-mg Noyes Formula A/I rodent pellets to the feeder tray. The center of the cuelight was located 14 cm above the floor and directly over the feeder opening. The cuelight remained on except during pellet deliveries when it was off for approximately 0.25 s. A microcomputer connected to the chamber was used to program events in the chamber and to record relevant data.

Procedure

Each of the 10 rats was trained to press the left lever by means of hand shaping, and 50 food pellets were administered on a continuous reinforcement schedule with every lever press followed by a food pellet. Following this, pairs of rats were randomly assigned to each of five conditions and were placed on the schedule appropriate to that condition, as shown in Table 1. Table 1 also shows the number of sessions of exposure to each schedule. One pair of rats was exposed to FI 30 s from the outset; two pairs were exposed to only one history schedule (DRL 20 s or FR 20) prior to exposure to FI 30 s; and two more pairs were exposed to both DRL 20 s and FR 20, but in different orders, prior to exposure to FI 30 s. On the FI 30-s schedule,

Table 1

Schedule sequence and, in parentheses, the number of sessions of exposure to each schedule. In the case of pairs of numbers, the first represents the total number of sessions on that schedule and the second represents the number of sessions after the attainment of FR 20 or DRL 20 s.

Rat	Phase 1	Phase 2	Phase 3
1			FI 30 (134)
2			FI 30 (80)
9		DRL 20 (55/30)	FI 30 (99)
10		DRL 20 (55/30)	FI 30 (99)
13		FR 20 (55/30)	FI 30 (103)
14		FR 20 (55/30)	FI 30 (96)
15	FR 20 (55/30)	DRL 20 (90/55)	FI 30 (85)
16	FR 20 (55/30)	DRL 20 (90/55)	FI 30 (90)
11	DRL 20 (55/30)	FR 20 (90/55)	FI 30 (79)
12	DRL 20 (55/30)	FR 20 (90/55)	FI 30 (80)

the first lever press following the passage of 30 s, timed from the previous food delivery, resulted in delivery of a food pellet. On the FR 20 schedule, every 20th lever press produced a food pellet. On the DRL 20-s schedule, each lever press with an interresponse time of at least 20 s yielded a food pellet.

For rats trained on DRL in Phase 1 or 2, the time requirement was increased over sessions in 2-s increments to avoid extinction of the lever-pressing response. For rats placed on FR 20 in Phase 1 or 2, the ratio was increased over sessions in increments of two to avoid ratio strain. Exposure to either DRL 20 s or FR 20, once attained, was continued until response rates appeared to have stabilized for all rats.

Following the attainment of apparent stability in response rates on their designated history schedules, the history rats were switched to FI 30 s. Rats remained on FI, regardless of prior history, for at least 80 sessions. If after 80 sessions, response rates appeared to be rising or falling, additional sessions were conducted until in the judgment of the investigator, response rates appeared to be stable. There were at least six daily sessions per week, and sessions were 15 min during all phases.

RESULTS

Response Rate

The decision to terminate exposure to any given schedule, including the target schedules, was based on inspection of the graphed response rates after the rat had completed a minimum of 80 sessions. If the graphed sessional response rates did not appear to be systematically increasing or decreasing, exposure to that schedule was terminated. Nonetheless, a mathematical stability assessment was subsequently made over the last 20 sessions on each schedule. The stability statistic showed that in most cases the mean overall response rate during the last 10 sessions and the second-to-last 10 sessions on any schedule fell within ±10% of the mean overall response rate during the last 20 sessions on that schedule. The data from Rat 2 during FI and Rats 12 and 13 during FR failed to meet this criterion, although the FR data for Rat 13 lay just outside the 10% limits. These results provided additional evidence that response rates had generally become stable by the end of each phase of the experiment.

The top two panels in Figure 1 show session-by-session FI response rates on a logarithmic scale for Rats 1 and 2. These 2 rats were exposed only to FI 30 s and provided a control condition against which to assess the effects of schedule history on FI. Rat 2 became ill and data could be collected for only 80 sessions. The physical condition of this rat may have contributed to its failure to meet the stability criterion. The data for Rat 1, however, show a remarkably stable response rate of about 7.0 responses per minute almost from the outset of training.

The next four panels of Figure 1 show data for those rats exposed to only one history schedule prior to FI. The graphs portray response rates during all FI sessions and for the last 20 sessions of the history schedules. The break in these curves indicates the change from the history schedule to the FI. There is little evidence in any animal's performance of a permanent effect on FI response rate of either the low response rates generated by the DRL or the high response rates generated by the FR. The data reveal a general tendency for FI response rates to decrease following FR and to increase following DRL. Overall, the decrease following FR is greater than the increase following DRL. Although the changes in FI response rate appeared to be relatively linear for 3 of the 4 rats, the FI response rates for Rat 10 appear to have reached asymptote after only about 10 sessions.

The last four panels in Figure 1 show data for rats that were exposed to two schedules before being placed on FI. These graphs show session-by-session response rates during all FI sessions and for the last 20 sessions of both history schedules that preceded FI. Again, there is little evidence of any permanent effect on FI response rates by the second history schedule (DRL for Rats 15 and 16 and FR for Rats 11 and 12). The FI response rates immediately following DRL increased, whereas those following FR decreased. The FI sessional response rates for Rat 12 did meet the stability criterion, but these data were quite variable. As with the data shown in the previous four panels, the decline in FI response rates following FR was greater than the increase in FI response rates following DRL. The changes in FI response rate were relatively linear for Rats 12 and 16, but the increase for Rat 15 occurred mainly toward the end of FI exposure and the decrease for Rat 11 seemed to be complete after only about 20 sessions.

The data suggest that the effect on FI response rate of exposure to an immediately preceding schedule was not altered by exposure to a different schedule even before that. The final FI response rates shown by Rats 9 and 10, which were exposed only to DRL prior to FI, are not different from those demonstrated by Rats 15 and 16, which were exposed to FR prior to DRL. Three of these 4 rats had response rates in the region of eight responses per minute during the final 20 sessions of FI. Similarly, the final FI response rates exhibited by Rats 13 and 14, which were exposed only to FR prior to FI, were not systematically different from those of Rats 11 and 12, which were exposed to DRL prior to FR. Three of these rats had response rates ranging from three to eight responses per minute during the final 20 sessions of FI. Only Rats 9 and 11 showed FI response rates consistently above 10 responses per minute during the final 20 sessions on FI. However, there is no consistent trend here either; the FI exposure for Rat 11 followed two history schedules whereas that for Rat 9 followed only one history schedule.

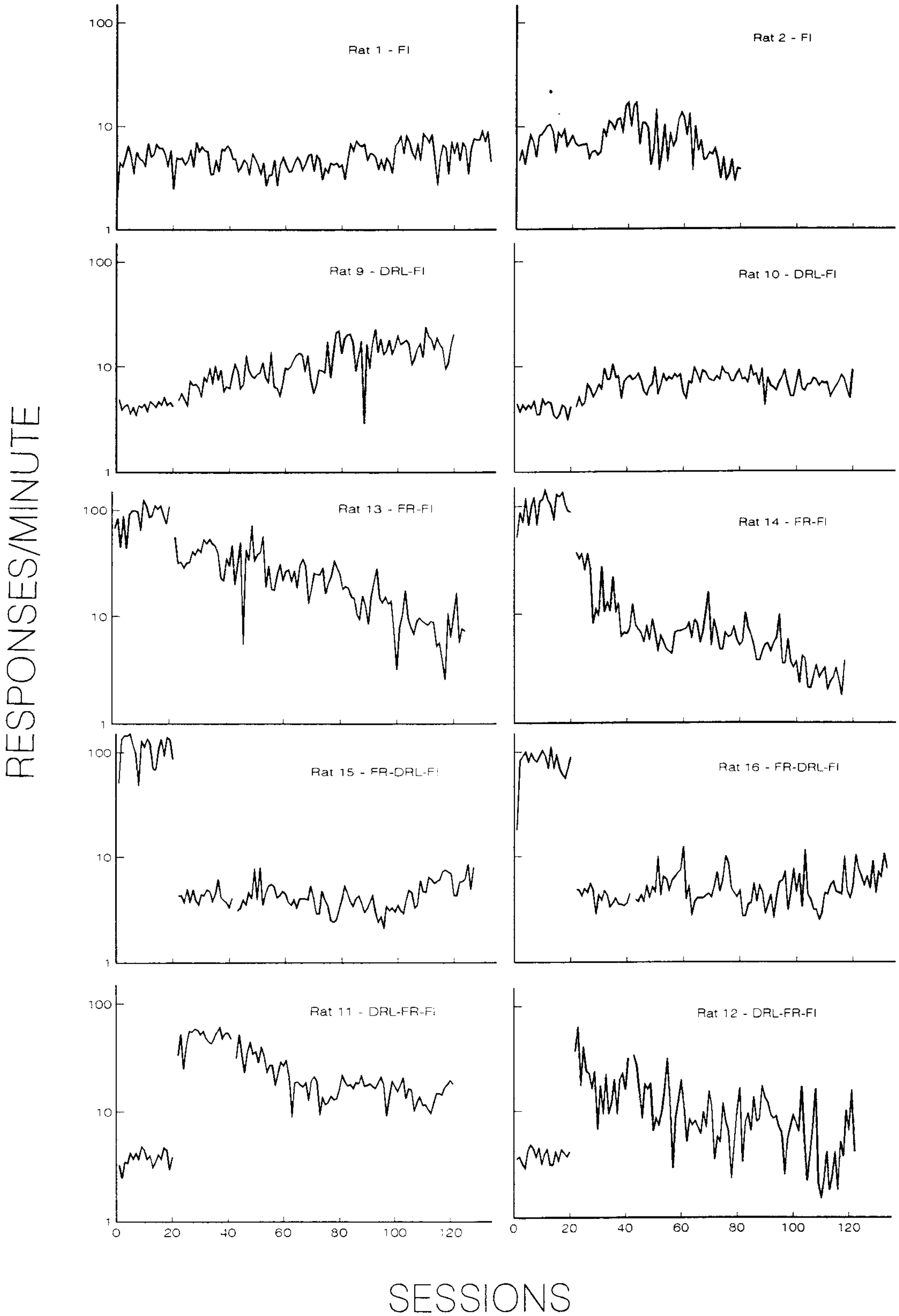
Table 2 shows mean response rates and reinforcement rates, both accompanied by standard deviations, over the last 20 sessions of FI and any preceding schedule for each of the 10 rats. There is no evidence of differences in mean FI response rate during the last 20 sessions that can be attributed to differences in schedule history. In fact, most of the FI response rates were relatively similar by the end of training. The differences that exist cannot be attributed to a specific schedule history. Rat 9, which showed the highest overall FI response rate over the last 20 sessions, had no FR exposure at all, whereas Rat 14, which showed the lowest terminal FI response rate, had no DRL exposure at all. It may be noted that Rat 11 also had a relatively high FI response rate, but it seems unlikely that this can be attributed directly to the immediately preceding FR exposure because this rat showed the second-to-lowest response rate on FR.

FI was the target schedule of primary interest in the present research, but the second history schedule also produced some interesting data. First, as Table 1 shows, it took nearly twice as many sessions (90) to achieve stability in Phase 2 for Rats 11, 12, 15, and 16 as it took in Phase 1 (55). Second, the only evidence of any long-term schedule history effects are seen in the FR performance of Rats 11 and 12. Table 2 shows that for both rats, the final response rate on FR, which followed DRL exposure, was substantially lower than that achieved by the 4 rats that were exposed to FR from the outset, even after 55 sessions on FR 20.

Response Patterns

Figure 2 shows the percentage of FI responses falling in successive 5-s bins during the FI 30-s schedule for all rats. For purposes of clarity of presentation, the reinforced response is included in the sixth bin. The data are in the form of means representing performance in successive blocks of 20 sessions over the first 80 sessions. As such, it should be noted that the apparent smooth scalloping revealed in averaged data can come from performance within individual interreinforcement intervals that is quite variable and not necessarily smoothly scalloped.

The top two panels in Figure 2 show data for the 2 rats that were exposed only to FI. For both rats, even during the first 20 sessions, there is a progressive increase in the percentage of responses allocated to successive bins. Moreover, the graphs show that over



RESPONSES/MINUTE
Rat 1 - FI
Rat 2 - FI
Rat 9 - DRL-FI
Rat 10 - DRL-FI
Rat 13 - FR-FI
Rat 14 - FR-FI
Rat 15 - FR-DRL-FI
Rat 16 - FR-DRL-FI
Rat 11 - DRL-FR-FI
Rat 12 - DRL-FR-FI
100
10
1
0
20
40
60
80
100
120
SESSIONS

the next 60 sessions there was a steady shift of responses away from the first four bins and into the sixth bin, although the number of responses in the sixth bin falls off slightly for Rat 1 in the final set of 20 sessions. An examination of the data from the fourth block of sessions shows little difference in the shape of the distribution for Rats 1 and 2.

The next four panels in Figure 2 reveal the same type of pattern for rats that experienced only a single schedule before FI. As was the case for the control rats, the data reveal a curvilinear distribution even during the first 20 sessions on FI. The graphs also reveal a progressive shift of responses from the first four bins to the sixth bin over the next 60 sessions for all 4 rats. Again, the data from the fourth block of sessions show little difference in the shape of the final distribution for any of the rats exposed to only a single schedule prior to FI.

The final four panels in Figure 2 show the emergence of patterns for rats that experienced two schedules before FI. As was the case for all the previous rats, the data reveal curvilinearity, even during the first 20 sessions on FI. With these 4 rats, however, the shift of responses from the first four bins to the last bin seems to have been completed by the end of 60 sessions, and there appears to be little additional change over the final 20 sessions depicted in these graphs. That said, however, the data from the fourth block of sessions once again reveal little difference in the shape of the final distribution for any of the rats that had exposure to two previous schedules.

Thus, the final pattern appeared to have been reached a little more rapidly for the rats with two previous schedule exposures, but the end point was the same for all rats. Overall, there seems to be little evidence that patterning was ultimately affected by schedule history.

Table 3 shows quarter lives (Herrnstein & Morse, 1957) for the last 20 sessions on FI for all rats. Quarter life is the percentage of time that one has to go in the interfood interval to find the point at which 25% of the interfood responses have been made. If responding were evenly distributed within the interfood interval, one would find 25% of the responses having been made 25% of the way into the interval. With a skewing of responding towards the latter part of the interfood interval on FI, on the other hand, 25% of the responses will not be made until more than 25% of the interval has passed. Table 3 reveals large values for this statistic, ranging from about 65% to 82%, indicating a strong tendency for FI responding to be distributed towards the end of the interfood interval. In addition, the data reveal no evidence of any real difference in the interfood-interval response distributions, as measured by quarter life, for rats exposed to FI from the outset or for rats with any type of schedule history.

Figure 3 shows FI 30-s cumulative records from individual rats from the first 12 min of the 10th-to-last session on FI. The records show that the smooth curves revealed in Figure 2 are often not present in the individual cumulative records. Almost without exception, the interfood intervals are characterized by a break-and-run pattern interspersed with occasional very low rates of responding, runs of responding, and the very occasional smooth scallop. More important, however, the records reveal no evidence of any pattern differences related to type or amount of prior history.

In summary, the pattern data do not reveal any evidence of differences can be attributed to specific prior schedule histories. Whether the previous schedule history was DRL, FR, DRL FR, FR DRL, or none, the patterning on FI emerges rapidly and to a similar degree.

DISCUSSION

Taken together, these data show no evidence that FR and DRL schedule histories permanently affect performance on an FI 30-s schedule. Without exception, the FI response rates and the FI interfood-interval response patterns eventually became indistinguishable in rats that were previously exposed to FR or to DRL in any combination or from

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Fig. 1. Session-by-session response rates, shown on a logarithmic scale, over the last 20 sessions of history schedules (FR or DRL) and over all sessions of the target FI 30-s schedule, whether preceded by history schedules or not.

Table 2

Mean response rates and reinforcement rates over the last 20 sessions on FI and on history schedules. The sequence of schedules under the Schedules column corresponds to the order used in Phases 1, 2, and 3, respectively. Standard deviations are in parentheses.

		Response rates			Reinforcement rates		
Rat	Schedules	Phase 1	Phase 2	Phase 3	Phase 1	Phase 2	Phase 3
1	— — FI			6.2 (1.71)			1.6 (0.24)
2	— — FI			5.5 (2.49)			1.6 (0.18)
9	— DRL FI		4.3 (0.39)	15.8 (3.50)		0.9 (0.20)	1.9 (0.11)
10	— DRL FI		4.0 (0.51)	6.8 (1.10)		1.1 (0.17)	1.8 (0.04)
13	— FR FI		89.7 (21.10)	8.0 (2.86)		4.5 (1.06)	1.7 (0.15)
14	— FR FI		100.0 (24.40)	2.9 (0.67)		5.0 (1.24)	1.3 (0.19)
15	FR DRL FI	110.0 (30.90)	4.3 (0.63)	6.1 (1.14)	5.5 (1.54)	1.1 (0.20)	1.6 (0.09)
16	FR DRL FI	81.3 (17.30)	4.1 (0.66)	6.4 (2.11)	4.1 (0.66)	1.1 (0.19)	1.7 (0.11)
11	DRL FR FI	3.8 (0.59)	49.5 (9.50)	14.5 (3.12)	0.8 (0.19)	2.4 (0.44)	1.9 (0.06)
12	DRL FR FI	3.8 (0.53)	22.2 (13.0)	5.9 (4.88)	0.9 (0.20)	1.1 (0.65)	1.2 (0.29)

those of 2 rats whose previous history included only a brief exposure to continuous reinforcement.

With respect to response rate, the results of the present experiment are, in a sense, consistent with all previous research. After 80 to 100 sessions, the present results are similar to the data reported by Baron and Leinenweber (1995) and Freeman and Lattal (1992), who also tested FI over a large number of sessions. On the other hand, after only about 40 sessions, the data from the present study resemble those offered by Johnson et al. (1991), LeFrancois and Metzger (1993), Urbain et al. (1978), Wanchisen et al. (1989), and Weiner (1969) in showing residual effects of schedule history on response rate. All of these latter studies reported data based on fewer sessions of exposure to the target schedule that were uninterrupted by some change in conditions. Collectively, the results of the research to date support the following generalization: Provided that training on FI is sufficiently extensive, schedule history effects dissipate.

The only evidence of a more-than-transitory effect of schedule history on response rate in the present data was seen in the FR performance of Rats 11 and 12. For both of these rats, FR exposure was preceded by DRL training. The final FR response rates for these 2 rats were less than half those shown by the 4 rats exposed to FR without a prior history. This was not a transitory effect, in that Rats 11 and 12 received a total of 90 sessions in Phase 2 of the experiment, 55 of these on the final FR 20 schedule. On the other hand, it must be noted that these observations were derived from just 2 rats, and in the case of Rat 12 the FR response rate was quite vari-

Table 3

Means and standard deviations of quarter lives over the last 20 sessions on FI.

Rat	History	Quarter life	*SD*
1		75.3	3.8
2		64.7	15.9
9	DRL	82.0	3.8
10	DRL	73.6	5.4
13	FR	77.6	7.8
14	FR	67.8	12.8
15	FR DRL	66.0	14.9
16	FR DRL	66.2	17.0
11	DRL FR	77.3	2.3
12	DRL FR	78.2	8.4

able. It is interesting that Cohen et al. (1994) found no evidence of history effects in PR schedules. Further research will be required to learn more about the effects of schedule history on ratio schedules.

The design of the present study provided an opportunity to examine the effects on FI response rate of both an immediately preceding schedule and a schedule that was once removed from the target sessions. LeFrancois and Metzger (1993) compared the effects on FI response rate of prior exposure to DRL alone or to DRL followed by FR. They reported that only the schedule immediately preceding FI training had any effect on FI. The present experiment provided an assessment of the effects on FI response rate of prior exposure to all possible combinations of FR and DRL, singly or together. The results replicated and extended the findings of LeFrancois and Metzger in showing that only the immediately preceding schedule had any identifiable impact on response rate on the target FI schedule. Moreover, the present data showed that the effect of the immediately preceding schedule on target FI response rate was not altered when that schedule was itself preceded by a different history schedule.

With respect to response patterns during the interfood interval, the present results are in agreement with Baron and Leinenweber (1995) and Freeman and Lattal (1992), in that the eventual interfood-interval pattern of responding on FI was break and run or scalloping, not the steady rate of response reported by Weiner (1969) for humans. The present data fail to support Weiner's hypothesis that a variable schedule history in nonhumans produces the pattern of responding on FI that he found for humans. Wanchisen et al. (1989) did support Weiner's hypothesis by finding that interfood-interval response rates on FI were high and steady following VR training, but the response-rate data from that experiment showed that FI training had not been sufficiently extensive to expunge the effects of the VR history at the time the data were collected. Thus, the present results add to the body of evidence suggesting that, whatever the cause of steady-state FI responding in humans, it is not likely to be variability in schedule history.

The interfood-interval patterning data from the present study are consistent with the findings from most of the previous research that has examined such response patterning in FI following schedule histories. As with the present research, both Baron and Leinenweber (1995) and Freeman and Lattal (1992) reported that after extended training on FI, responding during interfood intervals consisted mainly of break-and-run patterns, whether FI followed a previous reinforcement schedule or not. Only Wanchisen et al. (1989) found different patterns of interfood-interval responding when FI followed a previous schedule and when FI was in place from the outset. As was noted earlier, however, response-rate data in the Wanchisen et al. study showed that FI exposure had been insufficient to completely eliminate the effects of the prior VR history.

The patterning data in the present research did suggest that variability in prior history might have been relevant in determining the *rate* at which patterning developed on FI 30 s. Patterning seems to have developed more rapidly when FI was preceded by two previous schedule histories rather than by just one. However, further research will be needed to determine whether it is the overall amount of previous training or the number of different previous exposures that is important here. In the present research, the rats that were given two schedule histories had almost 100 more sessions of lever-press training before being placed on FI than the rats exposed to just one history schedule. Rate of acquisition of patterning aside, however, there was no evidence in the present research that exposure to two schedules over a greater number of sessions led to differences in the eventual patterning of responding within interfood intervals.

The patterning data from the present study

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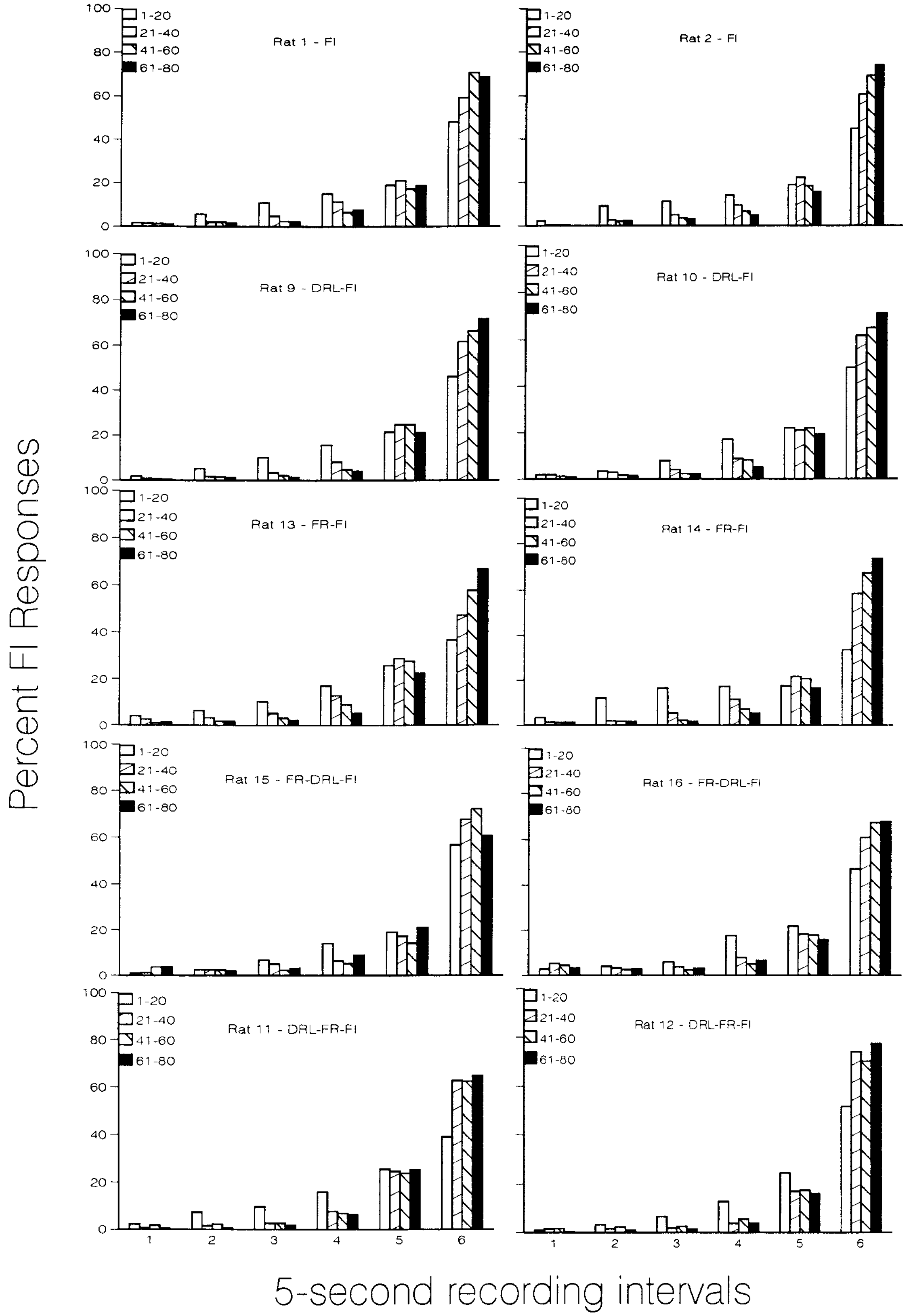
Fig. 2. Mean percentage of FI responses in successive 5-s bins throughout each interfood interval, and in successive 20-session blocks, over the first 80 sessions of the target FI 30-s schedule, whether preceded by history schedules or not.


Rat 1 - FI
Rat 2 - FI
Rat 9 - DRL-FI
Rat 10 - DRL-FI
Rat 13 - FR-FI
Rat 14 - FR-FI
Rat 15 - FR-DRL-FI
Rat 16 - FR-DRL-FI
Rat 11 - DRL-FR-FI
Rat 12 - DRL-FR-FI
1-20
21-40
41-60
61-80
Percent FI Responses
5-second recording intervals

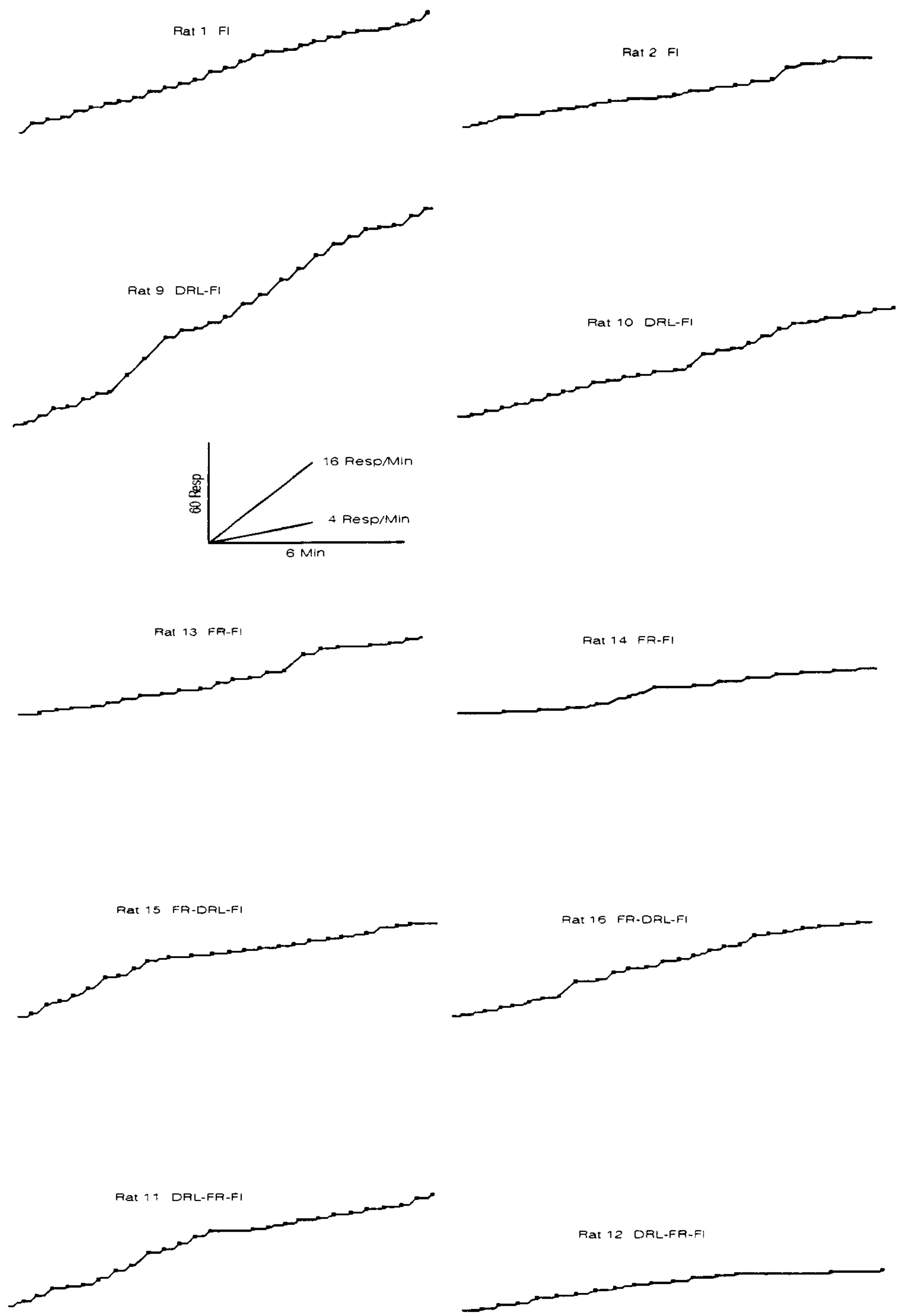


Fig. 3. Cumulative records from individual rats during the first 12 min of the 10th-to-last FI 30-s session. Food deliveries are represented by small filled squares.

also reemphasize the importance of not relying completely on aggregate results in the experimental analysis of behavior. Although the mean percentage response allocations shown in Figure 2 suggested that responding within the interfood intervals on FI was smoothly scalloped, the individual cumulative records shown in Figure 3 revealed that a break-and-run pattern, mixed with a few instances of very low response rates, runs of responding, and the occasional scallop, was more typical. Baron and Herpolsheimer (1999) have recently made a similar point regarding postreinforcement pauses in FR schedules.

The present research suggests that patterning might be a more sensitive measure of schedule history effects than is response rate. One direction that future research might take would be to examine history manipulations designed to affect patterning rather than response rate. For instance, schedules that produce different patterns of response could be used to create different histories of response distribution. Then the effect of these histories on response distributions in a variety of schedules could be examined. Finally, additional research also might be designed to explore a wider range of parameters in FI and other schedules. The interfood intervals associated with the FI schedules examined in this and other research studies were very short.

In conclusion, these data suggest that although exposure to various schedules of reinforcement does not leave a permanent imprint on FI performance, the effects can be relatively long lasting. As a result, researchers who expose subjects to various schedules should take care to ensure that response rates are stable before drawing conclusions about the effect of some manipulation and before introducing yet more changes.

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